

**The Parameterization of Top-Hat Particle Sensors with
Microchannel-Plate-Based Detection Systems and its Application to the
Fast Plasma Investigation on NASA's Magnetospheric MultiScale Mission**

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The most common instrument for low energy plasmas consists of a top-hat electrostatic analyzer geometry coupled with a microchannel-plate (MCP)-based detection system. While the electrostatic optics for such sensors are readily simulated and parameterized during the laboratory calibration process, the detection system is often less well characterized. Furthermore, due to finite resources, for large sensor suites such as the Fast Plasma Investigation (FPI) on NASA's Magnetospheric Multiscale (MMS) mission, calibration data are increasingly sparse. Measurements must be interpolated and extrapolated to understand instrument behavior for untestable operating modes and yet sensor inter-calibration is critical to mission success. To characterize instruments from a minimal set of parameters we have developed the first comprehensive mathematical description of both sensor electrostatic optics and particle detection systems. We include effects of MCP efficiency, gain, scattering, capacitive crosstalk, and charge cloud spreading at the detector output. Our parameterization enables the interpolation and extrapolation of instrument response to all relevant particle energies, detector high voltage settings, and polar angles from a small set of calibration data. We apply this model to the 32 sensor heads in the Dual Electron Sensor (DES) and 32 sensor heads in the Dual Ion Sensor (DIS) instruments on the 4 MMS observatories and use least squares fitting of calibration data to extract all key instrument parameters. Parameters that will evolve in flight, namely MCP gain, will be determined daily through application of this model to specifically tailored in-flight calibration activities, providing a robust characterization of sensor suite performance throughout mission lifetime. Beyond FPI, our model provides a valuable framework for the simulation and evaluation of future detection system designs and can be used to maximize instrument understanding with minimal calibration resources.